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Set Name side by side	Query	Hit Count	Set Name result set
	DB=USPT; PLUR=YES; OP=ADJ		
L33	variance and l19	0	L33
L32	l19 and matri$3	0	L32
L31	l19 and matri$2	0	L31
L30	(covariance or co$1variance) and l19	0	L30
L29	filter$4 and l19	1	L29
L28	l19 and (kalman filter$4)	0	L28
L27	l19 and kalman filter	0	L27
L26	l19 and gaussian	1	L26
L25	l19 and object	2	L25
L24	stab$7 and l19	0	L24
L23	mov$6 and l19	2	L23
L22	l19 and ((stable or fix$2) same (object))	1	L22
L21	l19 and ((stable or fix$2) near (object))	0	L21
L20	l19 and ((stable or fis$2) near (object))	0	L20
L19	(5572428 or 5613039).pn.	2	L19
L18	l17 and forward	0	L18
L17	l9 and (yaw near3 sens$3)	1	L17
L16	ang$4 and l14	1	L16
L15	l14 and yaw	0	L15
L14	5613039.pn.	1	L14
L13	colli$4 and L12	25	L13
L12	l9 and l11	162	L12
L11	((control$4 or processor or microprocessor or micro$1processor) same (sens$3 or detect$3) same (predict$3 or warn$3 or provid$3))	84156	L11
L10	(avoid$4 same colli$4 same vehicle) and L9	8	L10
L9	probability density function	1461	L9
L8	yaw and l7	1	L8
L7	(sens$3 or detect$3) and L6	4	L7
L6	l3 and colli$4	4	L6
L5	l3 and colli$3	1	L5
L4	(yaw rate sensor) and L3	0	L4
L3	(6067031 or 6151539 or 6161071 or 6173231 or 6199001 or 6223118).pn.	6	L3
L2	(yaw rate sensor) and L1	11	L2

L1	avoid$4 same colli$3 same vehicle	127	L1

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Search Results -

Term	Documents
VARIANCE.USPT.	31453
VARIANCES.USPT.	11362
(19 AND VARIANCE).USPT.	0
(VARIANCE AND L19).USPT.	0

Database:
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L5	l3 and colli$3	1	L5
L4	(yaw rate sensor) and L3	0	L4
L3	(6067031 or 6151539 or 6161071 or 6173231 or 6199001 or 6223118).pn.	6	L3
L2	(yaw rate sensor) and L1	11	L2
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Search: (5572428 or 5613039).pn.

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L1	avoid$4 same colli$3 same vehicle	127	L1

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L10: Entry 7 of 8 File: USPT Mar 18, 1997

DOCUMENT-IDENTIFIER: US 5613039 A
TITLE: Apparatus and method for motion detection and tracking of objects in a region for collision avoidance utilizing a real-time adaptive probabilistic neural network

Brief Summary Text (9):
It has been proposed by Donald F. Specht, in his article, "Probabilistic Neural Networks for Classification, Mapping, or Associative Memory", published in the Proceedings of the 1988 IEEE International Conference on Neural Networks, Vol. 1, pp. 525-32, July 1988, to use a probabilistic neural network (PNN) to recognize input signals based upon a priori test data. Specht proposed using a PNN to search incoming data signals for a priori data patterns. The a priori test data is essentially a library or directory of patterns representing a database for the system. The probabilistic neural network developed by Specht is a multi-layer feed-forward network which uses sums of Gaussian distributions to estimate a probability density function based upon a group of a priori training patterns. The estimated probability density function is then used to sort and match new input data to the a priori training patterns.

Brief Summary Text (10):
In another article, "The Use of Probabilistic Neural Networks to Improve Solution Times for Hull-To-Emitter Correlation Problems", published by the International Joint Conference on Neural Networks, Vol. 1, pp. 289-94, June 1989, P. Susie Maloney and Donald F. Specht disclose applying a probabilistic neural network to hull-to-emitter correlation problems for electronic intelligence (ELINT) systems. However, this process operates utilizing already sorted pulse data and does not use a probabilistic neural network for real time, non a priori pulse sorting. Real time, non a priori pulse sorting is difficult because real data input signals are often noisy, inaccurate, and corrupt with additional or missing signal parameter components and information. In addition, the output probability density function for a specific signal emitter may have multiple disjoint boundaries where an individual boundary may be overlapped with another emitter probability density function. Such input signal parameters cannot be accurately approximated by an n-dimensional Gaussian distribution as proposed by Specht.

Brief Summary Text (12):
Collision warning radar systems have only recently been tested and incorporated for use in motor vehicles. Studies have determined the benefit of including collision warning devices in motor vehicles stating that sixty percent of roadway collisions could be avoided if the operator of the vehicle was provided warning at least one-half second prior to a collision. Current collision warning systems operate by attempting to measure the relative position, speed and direction of objects to determine whether the objects being monitored are moving closer or farther away (i.e., presenting a greater or lesser threat of collision) from the motor vehicle. These systems are relatively unreliable and often reach alarm condition prematurely or at a time when the collision can not be avoided. In addition, current collision warning systems are incapable of reliably tracking a plurality of closely located objects (i.e., cars, highway dividers, trees, barriers, etc.) and are incapable of reliably determining if an object is presenting a greater or lesser danger for collision so as to provide adequate warning of a potential collision.

Brief Summary Text (20):
The cluster processor circuit includes an input buffer memory circuit essentially consisting of a group of serially connected memory circuits (i.e., registers). Input

20

parameter data signals which are provided to the neural network by the interferogram detector/converter are temporarily stored in the serially connected memory circuits of the input buffer memory circuit. The cluster processor circuit also includes a group of processing elements connected to the input buffer memory circuit, exponential function circuits coupled to corresponding processing elements and a summation circuit connected to each exponential function circuit. These components interact to generate a probability density function estimation value signal for the cluster processor circuit. The probability density function estimation value signal is generated by using both assigned input parameter data signals temporarily stored in the memory circuits and current unassigned input molecular parameter data signals. The probability density function estimation value signal of a cluster processor circuit represents the probability that the current unassigned input parameter data signal closely matches or belongs to the group of assigned input parameter data signals currently stored in the corresponding cluster processor circuit.

Brief Summary Text (21):
The decision logic circuit is coupled to the summation circuit of each cluster processor circuit. The decision logic circuit compares the output signal of each summation circuit to at least a first threshold value signal, and more preferably, also to a second threshold value signal. The output signal of each summation circuit corresponds to a probability density function estimation value of the cluster processor circuit. The decision logic circuit comparison is made to determine if the probability density function estimation value signal is at least equal to the first threshold value signal, at most equal to the second threshold value signal, or less than the first threshold value signal and greater than the second threshold value signal. The comparison in the decision logic circuit occurs simultaneously for all currently operating cluster processor circuits. The sorting process can be characterized as an internal competition among the currently operating cluster processor circuits to determine which currently operating cluster processor circuit has the greatest probability density function estimation value signal and which assigned input molecular parameter data signal stored in the respective cluster processor circuit best matches the current unassigned input molecular parameter data signal.

Brief Summary Text (22):
The decision logic circuit is coupled to the switching circuit. The decision logic circuit generates and provides a decision address signal to the switching circuit. The decision address signal corresponds to the cluster processor circuit currently storing assigned input parameter data signals that best match the current unassigned input parameter data signal (i.e., the cluster processor circuit having the highest probability density function estimation value signal). If the probability density function estimation value signal of all currently operating cluster processor circuits is less than the first threshold value signal and less than the second threshold value signal, then the decision logic circuit provides a decision address signal to the switching circuit instructing the switching circuit to activate a previously non-operating cluster processor circuit.

Brief Summary Text (23):
The switching circuit receives both the decision address signal and the current unassigned input parameter data signal being scrutinized. The switching circuit then provides the current unassigned input parameter data signal to the input buffer memory circuit of the cluster processor circuit corresponding to the decision address signal transmitted by the decision logic circuit. The newly assigned input parameter data signal is temporarily stored in the first register of the input buffer memory circuit of the corresponding cluster processor circuit. When the current input parameter data signal is sorted and stored in the input buffer memory circuit, the previously stored input molecular parameter data signals are sequentially transmitted to the next register in the group of serially connected registers for further storage. Therefore, upon introduction of the current input parameter data signal to the first register, the assigned input parameter data signal that was previously stored in the first register is shifted to the second register of the input buffer memory circuit. Furthermore, the input parameter data signal stored in the second register is shifted to the third register and so on. The input parameter data signal that was in the last register of the input buffer memory

circuit is considered "outdated" and not valuable for determining the next probability density function estimation value signal. Accordingly, this "outdated" input parameter data signal is discarded and replaced by a subsequent input parameter data signal.

Brief Summary Text (24):
The switching circuit will activate a previously non-operating cluster processor circuit when the probability density function estimation value signal computed for all currently operating cluster processor circuits is less than the first and the second threshold value signals. For example, a probability density function estimation value signal of less than 10% for every currently operating cluster processor circuit indicates that the current unassigned input parameter data signal does not match the assigned input parameter data signals stored in the currently operating cluster processor circuits. Accordingly, a previously non-operating cluster processor circuit is activated to store the current unassigned input molecular parameter data signal. The new cluster processor circuit corresponds to a new sorting group. The newly assigned input molecular parameter data signal will be stored in the first register of the input buffer memory circuit of the newly activated cluster processor circuit.

Drawing Description Text (9):
FIG. 8 is a graphical representation of a probability density function decision boundary after sorting a first input sample.

Drawing Description Text (10):
FIG. 9 is a graphical representation of a probability density function decision boundary after sorting first and second input samples.

Drawing Description Text (11):
FIG. 10 is a graphical representation of a probability density function decision boundary after sorting first, second and third input samples.

Detailed Description Text (2):
Referring now to FIG. 1 of the drawings, a preferred real time data sorting adaptive probabilistic neural network (APNN) constructed in accordance with the present invention will now be described. The APNN includes a plurality of identical subunits commonly referred to as cluster processor circuits 10. Each cluster processor circuit may be classified as a currently operating cluster processor circuit, a newly operating cluster processor circuit or a non-operating cluster processor circuit. Each cluster processor circuit is operatively coupled to a decision logic circuit 11 and to a switching circuit 13. Each currently operating cluster processor circuit generates and provides a probability density function estimation value signal to the decision logic circuit. The decision logic circuit is also coupled to the switching circuit. The decision logic circuit generates and provides a decision address signal to the switching circuit. The decision address signal identifies the cluster processor circuit which results in correct sorting and temporary storage of a current unassigned input pulse parameter data signal 18.

Detailed Description Text (6):
The cluster processor circuit 10 also includes a summation circuit 17. The summation circuit is coupled to each of the plurality of exponential function circuits 16 of the respective cluster processor circuit. The output signal of each exponential function circuit is received by the summation circuit. The summation circuit processes the exponential function circuit output signals of the corresponding cluster processor circuit. The output signal of the summation circuit also represents the output signal of the corresponding cluster processor circuit. The output signal of the cluster processor circuit corresponds to a probability density function estimation value of the cluster processor circuit. A probability density function estimation value is simultaneously calculated for all currently operating cluster processor circuits. A probability density function estimation value signal represents the probability that the current unassigned input pulse parameter data signal matches or belongs to the group of assigned input pulse parameter data signals currently stored in the registers 14 of the pulse buffer memory circuit 19 of the respective cluster processor circuit. The cluster processor circuits 10 of the neural network system may employ parallel processing using transputers. A

suitable transputer which may be used is Part No. MTM-PC, which is a reconfigurable multi-transputer, manufactured by Inmos Corporation.

Detailed Description Text (7):
The decision logic circuit 11 is coupled to the summation circuit 17 of each cluster processor circuit 10. The decision logic circuit includes a plurality of comparators. The decision logic circuit is designed to compare the probability density function estimation value signal of each currently operating cluster processor circuit to at least a first threshold value signal. The comparison process occurs simultaneously for all currently operating cluster processor circuits. In response to this comparison, a decision address signal is generated and transmitted by the decision logic circuit to the switching circuit 13. The decision address signal represents the cluster processor circuit currently storing the assigned input pulse parameter data signals which best match the current unassigned input pulse parameter data signal. The decision address signal can correspond to any currently operating cluster processor circuit or it can activate a non-operating cluster processor circuit so that the pulse buffer memory circuit 19 of the newly operating cluster processor circuit will store the current input pulse parameter data signal.

Detailed Description Text (9):
A storage register circuit 12 is coupled to the switching circuit 13. The storage register circuit receives the current unassigned input pulse parameter data signal transferred by the switching circuit. The switching circuit transfers, to the storage register circuit, the input pulse parameter data signals which can not be properly sorted by the present sorting method. This assignment to the storage register circuit corresponds to a probability density function estimation value signal of the respective cluster processor circuit which is less than the first threshold value signal and greater than the second threshold value signal. The input pulse parameter data signal in the storage register is maintained for possible future analysis and processing. Therefore, the input pulse parameter data signal may be correctly sorted to one of the plurality of cluster processor circuits.

Detailed Description Text (10):
The operation of the real time adaptive probabilistic neural network (APNN) for data sorting, constructed in accordance with the present invention, will now be described. Initially, the registers 14 of the pulse buffer memory circuit 19 of each cluster processor circuit 10 are empty and contain no assigned input pulse parameter data signals. The APNN system is designed so that a priori training data does not have to be stored in the registers at the beginning of system operation in order to effectuate sorting. The APNN system operates to develop its own sorting groups as the current unassigned input pulse parameter data signals 18 are introduced to the system. The sorting groups are defined by an internal competition among cluster processor circuits 10. Each currently operating cluster processor circuit represents a different sorting group corresponding to a different type of input pulse parameter data signal received. If the calculated probability density function estimation value signal of each currently operating cluster processor is less than at least a first threshold value signal, then a match does not exist between the current unassigned input pulse parameter data signal and the assigned input pulse parameter data signal stored in each currently operating cluster processor circuit. Therefore, a previously non-operating cluster processor circuit will be activated to establish a newly operating cluster processor circuit for storing the current input pulse parameter data signal.

Detailed Description Text (18):
Initially, when the system is activated, only a first cluster processor circuit of the plurality of cluster processor circuits is "currently operating." All other cluster processor circuits within the APNN system are "non-operating." The APNN system is initialized by receiving and providing the first input pulse parameter data signal 18 into the currently operating first cluster processor circuit. As the first input pulse parameter data signal is introduced to the APNN system, it is provided to each processing element 15 of the currently operating first cluster processor circuit. A probability density function estimation value signal is then generated in the currently operating first cluster processor circuit by the combined effects of the processing elements, the exponential function circuits, and the summation circuit. The probability density function estimation value signal is

outputted by the summation circuit of the currently operating first cluster processor circuit according to the first input pulse parameter data signal.

Detailed Description Text (19):
The probability density function estimation value signal is generated according to the formula: ##EQU1## where PR=probability density function estimation value

Detailed Description Text (24):
Sigma=smoothing factor which represents the standard deviation of the probability density function (a constant set by the system operator)

Detailed Description Text (27):
The probability density function estimation value signal is generated by the currently operating first cluster processor circuit in the following manner. The current unassigned input pulse parameter data signal to be sorted is received and provided to each processing element 15 of the first cluster processor circuit. Each processing element determines a value for the expression: ##EQU2##

Detailed Description Text (29):
The summation circuit 17 adds all of the output signals of the exponential function circuits 16. The output signal of the summation circuit, which corresponds to the output signal of the cluster processor circuit 10, is a measure of the probability or likelihood that the current unassigned input pulse parameter data signal matches the assigned input pulse parameter data signal stored in the pulse buffer memory circuit of the respective cluster processor circuit. For example, a probability density function estimation value signal of 80% represents a high probability of correctly sorting the current unassigned input pulse parameter data signal if the current unassigned input pulse parameter data signal is stored in the respective cluster processor circuit. However, a probability density function estimation value signal of 10% represents a decisive mismatch for the current unassigned input pulse parameter data signal and the assigned input pulse parameter data signal stored in the respective cluster processor circuit.

Detailed Description Text (30):
The decision logic circuit 11 contains at least a first threshold value signal. The decision logic circuit receives and compares the probability density function estimation value signal of the currently operating first cluster processor circuit to at least the first threshold value signal. The decision logic circuit comparison determines whether the current unassigned input pulse parameter data signal should be stored in the currently operating first cluster processor circuit or whether a non-operating cluster processor circuit should be activated to store the current unassigned input pulse parameter data signal. A newly operating cluster processor circuit represents a new sorting classification of input pulse parameter data signals received. In the preferred embodiment, two threshold value signals are utilized. They are the 70% and 10% threshold value signals. If it is assumed that the probability density function estimation value signal for the currently operating first cluster processor circuit is at least equal to the 70% threshold value signal, then the current unassigned input pulse parameter data signal will be stored in the currently operating first cluster processor circuit. Therefore, after comparing the probability density function estimation value signal of the currently operating first cluster processor circuit with the 70% and 10% threshold value signals, the decision logic circuit will generate and provide a decision address signal to the switching circuit 13 corresponding to the currently operating first cluster processor circuit. The decision address signal directs the switching circuit to transmit the current unassigned input pulse parameter data signal to the first register of the pulse buffer memory circuit 19 for temporary storage.

Detailed Description Text (31):
If the probability density function estimation value of the currently operating first cluster processor circuit is at most equal to the 10% threshold value signal, then a decision address signal will be transmitted instructing the switching Circuit to activate a previously non-operating cluster processor circuit. The previously non-operating cluster processor circuit is now referred to as a newly operating cluster processor circuit. The switching circuit then transmits the current unassigned input pulse parameter data signal to the first register of the pulse

buffer memory circuit of the newly operating cluster processor circuit for temporary storage. The activation of the newly operating cluster processor circuit corresponds to a new type of input pulse parameter data signal received by the APNN system.

Detailed Description Text (32):
If the probability density function estimation value signal generated by the currently operating first cluster processor circuit is greater than the 10% and less than the 70% threshold value signals, then a different decision address signal is transmitted by the decision logic circuit 11 to the switching circuit 13. This decision address signal instructs the switching circuit to assign the current unassigned input pulse parameter data signal to a storage register circuit 12 for temporary storage. The input pulse parameter data signal stored in the storage register circuit is saved so that the APNN system can analyze the stored input pulse parameter data signal in greater detail at a later time. The input pulse parameter data signal stored in the storage register circuit is not used in subsequent calculations of probability density function estimation value signals. If desired, this unassigned input pulse parameter data signal stored in the storage register circuit can undergo a second level of analysis called deinterleaving. After the data has been deinterleaved, it can be sorted and stored in any currently operating or newly operating cluster processor circuit.

Detailed Description Text (33):
The probability density function estimation value signal graph for the first cluster processor circuit containing the first input pulse parameter data signal is shown in FIG. 3. The probability density function estimation is shown by a two variable, two dimensional graph of, for example, coarse AOA vs fine AOA, as shown by reference numeral 19. Similar graphs can be made having different coordinate axes corresponding to the types of parameters which represent the input pulse parameter data signal. From FIG. 3, it is possible to measure statistical properties and to determine sorting performance in a quantitative manner.

Detailed Description Text (34):
As a second unassigned input pulse parameter data signal (Pulse No. 2) enters the system, initialization is not needed because the system has been operating. Therefore, the current unassigned input pulse parameter data signal (Pulse No. 2) is provided to each processing element of the first cluster processor circuit. The previous input pulse parameter data signal (Pulse No. 1), which is stored in the first register of the pulse buffer memory circuit 19 of the currently operating first cluster processor circuit, is provided to the first processing element along with Pulse No. 2. All other registers of the first cluster processor circuit which do not contain data signals provide a logic zero to corresponding processing elements. Each processing element generates and provides a signal to the corresponding exponential function circuit 16. The summation circuit 17 transmits the output signal of the cluster processor circuit to the decision logic circuit 11. The decision logic circuit performs a series of comparisons to see whether the probability density function estimation value signal of the first currently operating cluster processor circuit corresponding to Pulse No. 2 is at least equal to the 70% threshold value signal, at most equal to the 10% threshold value signal, or greater than the 10% and less than the 70% threshold value signal. If it is assumed that the current unassigned input pulse parameter data signal (Pulse No. 2) has less than a 10% probability density function estimation value as determined by the currently operating first cluster processor circuit, then the decision logic circuit provides a decision address signal to the switching circuit 13 to activate a previously non-operating cluster processor circuit. This newly operating cluster processor circuit corresponds to a new classification of input pulse parameter data signals. The switching circuit then transmits the current unassigned input pulse parameter data signal (Pulse No. 2) to the first register of the pulse buffer memory circuit of the newly operating second cluster processor circuit. The current unassigned input pulse parameter data signal (Pulse No. 2) is now referred to as an assigned input pulse parameter data signal. The probability density function estimation value signal graph showing the first and second currently operating cluster processor circuits and the corresponding assigned input pulse parameter data signals is shown by reference numerals 19 and 20 in FIG. 4.

Detailed Description Text (36):

Assuming that the two currently operating cluster processor circuits compute a probability density function estimation value signal using Pulse No. 3, both probability density function estimation value signals are transmitted by the summation circuit of each currently operating cluster processor circuit to the decision logic circuit 11. Once again, the previously stated 10%-70% threshold value signal comparison occurs. However, if both currently operating cluster processor circuits have a probability density function estimation value signal of greater than 70%, then the decision logic circuit will output a decision address signal corresponding to the currently operating cluster processor circuit having the larger probability density function estimation value signal. Assuming that the probability density function estimation value signal of the first currently operating cluster processor is larger than the probability density function estimation value signal of the second currently operating cluster processor, and further assuming that both estimation value signals are greater than the 70% threshold value signal, then the decision logic circuit will provide a decision address signal to the switching circuit corresponding to the currently operating first cluster processor circuit. Therefore, the switching circuit 13 assigns the current unassigned input pulse parameter data signal (Pulse No. 3) to the first register of the pulse buffer memory circuit 19 of the currently operating first cluster processor circuit. Accordingly, the previously assigned input pulse parameter data signal (Pulse No. 1) that was stored in the first register of the pulse buffer memory circuit of the currently operating first cluster processor circuit is shifted to the second register of the pulse buffer memory circuit. For each new input pulse parameter data signal that is introduced to the pulse buffer memory circuit of the currently operating first cluster processor circuit, the assigned input pulse parameter data signal is shifted to the next register until the assigned input pulse parameter data signal reaches the end of the pulse buffer memory circuit. When the assigned input pulse parameter data signal reaches the end of the pulse buffer memory circuit, it is discarded.

Detailed Description Text (37):
FIG. 5 shows the probability density function estimation for the two currently operating cluster processors after the APNN system has received three input pulse parameter data signals. Reference numeral 21 represents the probability density function estimation value generated by the currently operating first cluster processor having two input pulse parameter data signals sorted therein.

Detailed Description Text (42):
In addition to the above description of radar pulse sorting, a probabilistic neural network can also be specifically utilized for assisting in the detection, identification and tracking of objects proximate to a motor vehicle for collision warning and avoidance. Collision avoidance systems typically emit modulated, continuous radio waves at specific frequencies and measure the reflected received signal. The reflected signal of the radio waves are typically shifted in the frequency domain if the object is moving. Therefore, the faster the monitored object is traveling, the more the frequency of the reflected signal is shifted.

Detailed Description Text (43):
Referring now to FIG. 6 of the drawings, a preferred apparatus for motion detection of objects in a region for collision avoidance constructed in accordance with the present invention will now be described. The apparatus may be placed at a variety of locations on a motor vehicle such as the front, sides and rear of the vehicle to provide collision avoidance protection. The apparatus for detecting motion of objects 50 includes a signal transmitter 52, electrically coupled to first and second signal generators 54,56. The signal transmitter 52 preferably includes first and second input ports which receive first and second detection signals provided by first and second signal generators 54,56. In addition, the signal transmitter includes at least one output port 62. The first and second detection signals generated by the signal generators preferably have substantially distinct signal frequencies. In a preferred embodiment, the frequencies of the first and second detection signals are separated by approximately 250 kHz. The signal generators may preferably be Gunn oscillators or dielectric resonant oscillators such as Part No. DE2011 manufactured by GEC Plessy Semiconductors of the United Kingdom. The signal generators may also include an amplifier to increase the power of the first and second detection signals before transmission. Alternatively, the signal transmitter 52 may include an amplifier or, amplifiers may be coupled between the first signal

generator 54 and the signal transmitter 52 or coupled between the second signal generator 56 and the signal transmitter 52. The signal transmitter 52 preferably provides the simultaneous transmission of the first and second detection signals.

Detailed Description Text (52):
The output ports 116,118 of the velocity and range finder 102 (the peak finder and subtractor) are preferably electrically coupled to a probabilistic neural network (PNN) processor 120 wherein each pulse buffer memory circuit of the PNN includes at least as many registers as the number objects being monitored by the motion detection and tracking apparatus for collision avoidance. The probabilistic neural network processor is preferably configured and operates as described with respect to FIGS. 1-5. Specifically, the probabilistic neural network receives the velocity and range finder output signal as inputs and, based upon previous velocity and range finder output signals, classifies a current velocity and range finder output signal utilizing a probability density function.

Detailed Description Text (53):
FIG. 8 illustrates a first probability density function contour map (range of object vs. relative velocity) for a first data sample 122 processed by the apparatus. The concentric rings indicate various probabilities of matching wherein the inner most circle represents the highest probability of matching and the outermost circle represents the lowest probability of matching. FIG. 9 illustrates a second probability density function map showing the first sample 122 and a second sample 124. Since the second sample is not within the probability density function regions set around the first sample, probability density function regions are set around the second sample. For each successive sample point, either a new probability density function region is included or, if the current sample point falls within one of the currently existing probability density function contours, the current probability density function contours are recomputed to show a new likelihood of a future sample point matter such as shown in FIG. 10 wherein a third sample point 126 and the first sample point are combined to indicate the likelihood of the next position of the object being monitored.

Detailed Description Text (56):
Two switch output signals (i.e., first and second object parameter data signals), corresponding to the first and second detection signals, are provided by the switch to a low pass filter for removing noise and unwanted signal components. The low pass filter output signals are provided to an analog to digital converter which converts the continuous radio frequency signals to digital signals. The digital first and second A/D converter output signals are provided to a Fourier transform circuit which transforms a time domain signal (the received first and second detection signals corresponding to the first and second object parameter data signals) to a frequency domain signal. From the frequency domain signals, the velocity and range of the object being monitored are respectively determined by identifying the peak amplitude of one of the first and second object parameter data signals and by taking the difference between the first and second object parameter data signals. The output signal of the velocity and range finder is thereafter provided to the probabilistic neural network for determining whether a current data sample is properly associated with a prior data sample shown on a current probability density function contour map or whether the new data sample corresponds to a new object in the field of view of the antenna. By utilizing the probabilistic neural network, it is possible to associate current data samples corresponding to the present location of objects in the antenna field of view based upon previous locations of objects in the field of view. Therefore, it is possible to determine if an object is moving farther away and therefore the threat of collision is decreasing, or whether an object is moving closer and therefore a threat of collision is increasing.

CLAIMS:

1. Apparatus for detecting and tracking motion of objects in a region for collision avoidance comprising:

a signal transmitter having an input port and an output port, the signal transmitter being responsive to first and second detection signals at the input port and transmitting the first and second detection signals from the output port to a

spatial region, the first and second detection signals at least partially reflecting off at least one object located in the spatial region, the first detection signal having a first signal frequency and the second detection signal having a second signal frequency, the first signal frequency being substantially distinct from the second signal frequency,

a signal receiver being electrically coupled to the transmitter, the receiver having an input port and an output port, the signal receiver being responsive to the at least partially reflected first and second detection signals respectively corresponding to first and second object parameter data signals,

a probabilistic neural network processor being electrically coupled to the signal receiver and being responsive to the first and second object parameter data signals, the probabilistic neural network providing an output signal indicative of the proximity of an object detected in the spatial region; said probabilistic neural network including:

(a) a plurality of cluster processor circuits being responsive to the first and second object parameter data signals, each cluster processor circuit generating an output signal representing a probability density function estimation value corresponding to the received first and second object parameter data signals, each cluster processor circuit including:

(1) an input buffer memory circuit, the input buffer memory circuit having a plurality of serially connected registers for storing the first and second object parameter data signals assigned to a respective cluster processor circuit;

(2) a plurality of processing elements, each of the processing elements being coupled to a corresponding register of the input buffer memory circuit and being responsive to assigned first and second object parameter data signals stored in the input buffer memory circuit, each of the processing elements further being responsive to current unassigned first and second object parameter data signals, each processing element providing an output signal;

(3) a plurality of exponential function circuits, each of the exponential function circuits being coupled to a corresponding processing element, each exponential function circuit performing an exponential function on the output signal of each processing element and providing an output signal in response thereto; and

(4) a summation circuit coupled to each of the exponential function circuits of the respective cluster processor circuit, the summation circuit being responsive to the output signals from the exponential function circuits, performing an addition function thereon and providing an output signal representing a probability density function estimation value for each unassigned first and second object parameter data signal;

(b) a decision logic circuit, the decision logic circuit being coupled to the summation circuit of each cluster processor circuit, the decision logic circuit comparing the output signal of each summation circuit of the corresponding cluster processor circuit with at least first and second threshold value signals, and providing a decision address signal in response thereto;

(c) a switching circuit, the switching circuit being coupled to the decision logic circuit and to each of the cluster processor circuits and further being responsive to current unassigned first and second object parameter data signals and assigning the current unassigned first and second object parameter data signals to a respective cluster processor circuit for storage in the input buffer memory circuit of the respective cluster processor circuit in response to the decision address signal from the decision logic circuit, the switching circuit being electrically coupled to the input buffer memory circuit of each cluster processor circuit, the switching circuit assigning the current unassigned first and second object parameter data signal to the input buffer memory circuit of a currently operating cluster processor circuit if the summation circuit output signal representing a probability density function estimation value of the currently operating cluster processor circuit is at least equal to the first threshold value signal, the switching circuit

assigning the current unassigned first and second object parameter data signal to the input buffer memory circuit of a newly operating cluster processor which was previously a non-operating cluster processor if the summation circuit output signal representing the probability density function estimation value of each currently operating cluster processor circuit is less than or equal to the second threshold value signal; and

(d) a storage register circuit, the storage register circuit being electrically coupled to the switching circuit, the switching circuit providing the current unassigned first and second object parameter data signals to the storage register circuit when the output signal of the summation circuit of each cluster processor circuit is less than the first threshold value signal and greater than the second threshold value signal, the unassigned first and second object parameter data signals being provided to the storage register circuit for later detailed analysis by the probabilistic neural network.

12. Apparatus for detecting and tracking motion of objects in a region for collision avoidance comprising:

a signal transmitter having an input port and an output port, the signal transmitter being responsive to first and second detection signals at the input port and transmitting the first and second detection signals from the output port to a spatial region, the first and second detection signals at least partially reflecting off at least one object located in the spatial region, the first detection signal having a first signal frequency and the second detection signal having a second signal frequency, the first signal frequency being substantially distinct from the second signal frequency,

a signal receiver being electrically coupled to the transmitter, the receiver having an input port and an output port, the signal receiver being responsive to the at least partially reflected first and second detection signals respectively corresponding to first and second object parameter data signals,

a Fourier transform circuit being electrically coupled to the signal receiver and being responsive to the first and second object parameter data signals, the Fourier transform circuit providing first and second Fourier transform object parameter data signals representing a spectral waveshape of the first object parameter data signal and the second object parameter data signal, and

a probabilistic neural network processor being electrically coupled to the Fourier transform circuit and being responsive to the first and second object parameter data signals, the probabilistic neural network providing an output signal indicative of the proximity of an object detected in the spatial region, the probabilistic neural network comprising:

(a) a plurality of cluster processor circuits being responsive to the first and second Fourier transform object parameter data signals, each cluster processor circuit generating an output signal representing a probability density function estimation value corresponding to the received first and second Fourier transform object parameter data signals, each cluster processor circuit including:

(1) an input buffer memory circuit, the input buffer memory circuit having a plurality of serially connected registers for storing the first and second Fourier transform object parameter data signals assigned to a respective cluster processor circuit;

(2) a plurality of processing elements, each of the processing elements being coupled to a corresponding register of the input buffer memory circuit and being responsive to assigned first and second Fourier transform object parameter data signals stored in the input buffer memory circuit, each of the processing elements further receiving current unassigned first and second Fourier transform object parameter data signals, each processing element providing an output signal;

(3) a plurality of exponential function circuits, each of the exponential function circuits being coupled to a corresponding processing element, each exponential

function circuit performing an exponential function on the output signal of each processing element and providing an output signal in response thereto; and

(4) a summation circuit coupled to each of the exponential function circuits of the respective cluster processor circuit, the summation circuit being responsive to the output signals from the exponential function circuits, performing an addition function thereon and providing an output signal representing a probability density function estimation value for each unassigned first and second Fourier transform object parameter data signal;

(b) a decision logic circuit, the decision logic circuit being coupled to the summation circuit of each cluster processor circuit, the decision logic circuit comparing the output signal of each summation circuit of the corresponding cluster processor circuit with at least first and second threshold value signals, and providing a decision address signal in response thereto;

(c) a switching circuit, the switching circuit being coupled to the decision logic circuit and to each of the cluster processor circuits and further being responsive to current unassigned first and second Fourier transform object parameter data signals and assigning the current unassigned first and second Fourier transform object parameter data signals to a respective cluster processor circuit for storage in the input buffer memory circuit of the respective cluster processor circuit in response to the decision address signal from the decision logic circuit, the switching circuit being electrically coupled to the input buffer memory circuit of each cluster processor circuit, the switching circuit assigning the current unassigned first and second Fourier transform object parameter data signals to the input buffer memory circuit of a currently operating cluster processor circuit if the summation circuit output signal representing a probability density function estimation value of the currently operating cluster processor circuit is at least equal to the first threshold value signal, the switching circuit assigning the current unassigned first and second Fourier transform object parameter data signals to the input buffer memory circuit of a newly operating cluster processor which was previously a non-operating cluster processor if the summation circuit output signal representing the probability density function estimation value of each currently operating cluster processor circuit is less than or equal to the second threshold value signal; anal

(d) a storage register circuit, the storage register circuit being electrically coupled to the switching circuit, the switching circuit providing the current unassigned first and second Fourier transform object parameter data signals to the storage register circuit when the output signal of the summation circuit of each cluster processor circuit is less than the first threshold value signal and greater than the second threshold value signal, the unassigned first and second Fourier transform object parameter data signals being provided to the storage register circuit for later detailed analysis by the probabilistic neural network.

15. A method of detecting and tracking motion of objects in a region for collision avoidance which comprises:

a) transmitting first and second detection signals having distinct frequencies for at least partial reflection by at least one object in a spatial region, the first detection signal having a first signal frequency and the second detection signal having a second signal frequency, the first signal frequency being substantially distinct from the second signal frequency;

b) detecting the first and second detection signals at least partially reflected by the object, the first and second detection signals corresponding to first and second object parameter data signals;

c) providing the first and second object parameter data signals to a probabilistic neural network for sorting the first and second object parameter data signals without the use of a priori training data, step (c) including the additional sub-steps of:

i) inputting current unassigned first and second object parameter data signals into

at least one of a plurality of processing elements contained within a plurality of currently operating cluster processor circuits;

ii) generating a first signal representing a probability density function estimation value in response to the first and second object parameter data signal of each currently operating cluster processor circuit of the plurality of cluster processors, the probability density function estimation value signal being generated using the current unassigned first and second object parameter data signals and using a plurality of assigned first and second object parameter data signals stored in an input buffer memory circuit of each currently operating cluster processor circuit;

iii) comparing the first signal representing the probability density function estimation value generated by each currently operating cluster processor circuit to at least first and second threshold value signals in a decision logic circuit;

iv) generating a decision address signal in response to the comparison of the first signal and the first and second threshold value signals, the decision address signal being provided to a switching circuit, the decision address signal denoting a currently operating cluster processor circuit when the first signal representing the probability density function estimation value is at least equal to the first threshold value signal, the decision address signal denoting and activating a non-operating cluster processor circuit when the first signal representing the probability density function estimation value is at most equal to the second threshold value signal;

v) assigning the current unassigned first and second object parameter data signal from the switching circuit to the cluster processor circuit corresponding to the decision address signal provided to the switching circuit;

vi) storing the current unassigned first and second object parameter data signal in the input buffer memory circuit of the cluster processor circuit according to the decision address signal received by the switching circuit; and

vii) denoting a storage register circuit and assigning the current unassigned first and second object parameter data signal from the switching circuit to the storage register circuit for temporary storage therein when the first signal, representing the probability density function estimation value, is less than the first threshold value signal and greater than the second threshold value signal, the unassigned first and second object parameter data signal being provided to the storage register circuit for later detailed analysis by the probabilistic neural network.